JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2024, 25(7), 212–223
https://doi.org/10.12911/22998993/188291
ISSN 2299–8993, License CC-BY 4.0

Received: 2024.04.09
Accepted: 2024.05.16
Published: 2024.06.01

Soil Study and Identification of Plant Species Growing Near Two Thermal Springs (Ain El Haouamed and Ain Hamra) in the Eastern Region of Morocco

Mohamed Mouchane[1*], Zineb Hazyoun[1], Hanan Taybi[1], Najat Assem[1], Kaoutar Bargach[2]

[1] Laboratory of Natural Substances, Pharmacology, Environment, Modeling, Health and Quality of Life, Polydisciplinary Faculty of Taza, Sidi Mohamed Ben Abdellah University, Fez, Morocco

[2] Geo-Biodiversity and Natural Patrimony Laboratory (GEOBIO), Geophysics, Natural Patrimony and Green Chemistry, Research Center, Scientific Institute, Mohammed V University in Rabat, Morocco

* Corresponding author's e-mail: mohamed.mouchane1@gmail.com

ABSTRACT

In order to deepen our understanding of the ecosystems around thermal springs and contribute to their preservation and enhancement, our study focused on the physico-chemical analysis of soils located in the immediate vicinity of two thermal springs Ain El Haouamed (S1) and Ain Hamra (S2) in the eastern region of Morocco. At the same time, we identified the plants that thrive in these areas and have developed specific adaptations to particular environmental conditions. The results of physico-chemical soil analyses revealed distinct characteristics. Around the first thermal spring (S1), the soil has a sandy loam texture, while around the second spring (S2), a clayey loam texture. The pH of both soils is slightly basic. In terms of organic matter, significant variations were observed between soil samples taken in these areas. Electrical conductivity and other physico-chemical parameters showed variable values. A study of the vegetation near the thermal springs shows the presence of (*Matricaria chamomilla, Juncus acutus, Carex sylvatica*) at site 1 and (*Tamarix gallica, Inula viscosa, Phragmites australis, Typha angustifolia*) at site 2. This information will certainly contribute to a better understanding of these specific thermal ecosystems. The present study has led to the identification of several plant species of great interest, representing an important advance in our knowledge of the biodiversity of these areas. These results can also be used to develop strategies for the preservation and sustainable management of these particular ecosystems.

Keywords: physicochemical properties, soils, plants, thermal waters.

INTRODUCTION

The study of soils irrigated by water from thermal springs is attracting growing interest because of its significant impact on soil quality and, consequently, on the diversity of plants growing there. Thermal springs are natural resources rich in minerals, often used for therapeutic purposes (Mourelle et al., 2023). When these waters are directed towards agricultural areas or surrounding ecosystems, they can have a significant impact on the chemical composition, structure and fertility of soils, with consequent repercussions on plant diversity. The dynamic relationship between water, soil and plants is fundamental to the harmonious functioning of ecosystems and the prosperity of crops (Al-Kayssi, 2023). Water, as a vital resource, plays an important role in plant growth, acting as an essential vector for the transport of nutrients and actively participating in photosynthesis. Irrigation water quality, including pH and salinity, can also have a significant impact on plant health and soil structure (Shin et al., 2022). In addition to water and soil, other elements such as temperature, light, soil ventilation and soil microbiota interact to shape the plant growth environment. A thorough understanding of these relationships is crucial to developing sustainable agricultural practices, promoting an optimal balance between these elements to ensure prosperous crops and healthy ecosystems.

This complex interaction between water, soil, plants and other factors raises crucial questions about the sustainability of agriculture, ecosystem preservation and the quality of native vegetation. This interaction can result in an improvement or deterioration in soil quality (Martínez Barroso and Vaverková, 2020; Akhter et al., 2023; Boujraf et al., 2023).

Our study aims to explore the physico-chemical aspects of soils irrigated by the thermal waters of Ain El Haouamed and Ain Hamra, examining how these influence soil composition, nutrient availability, and potential environmental impacts by identifying plants adapted to the particular conditions near these two thermal springs which are characterized by very high conductivity of these waters, due to their significant mineralization which can improve soil fertility and promote crop growth. This research is of vital importance for the wise management of natural resources, sustainable agricultural development and the preservation of our fragile ecosystems.

In order to examine the characteristics of the land adjacent to specific thermal springs, samples were taken in the spring of 2023 from two separate sites. The first site (S1) is located near the Ain el Haouamed spring in the province of Guercif, at a distance of 40 km from the city of Guercif. The second site (S2) is located near Ain Hamra, approximately 90 km north of the city of Taza. In addition, two other plots of land (T1 and T2), located at a distance of around 500 m from each spring, were included in the study as controls. In order to identify the plant species present and assess their diversity, taking into account the particular adaptations of these plants to soil and water characteristics, vegetation surveys were carried out in conjunction with the collection of soil samples in areas of spontaneous vegetation.

MATERIALS AND METHODS

The samples, weighing between 400 and 600 grams, were taken from a depth of 0 to 20 centimetres at each study site. After being exposed to the open air for a week, they were ground to a powder using a porcelain mortar, then sieved to a size of 2 millimeters before being bagged for physico-chemical analysis.

Soil texture characterization, total organic matter quantification, pH measurement, calcium carbonate identification, electrical conductivity evaluation, and determination of total nitrogen, phosphorus and potassium concentrations were all carried out at the École Nationale d'Agriculture in Meknes. Soil texture was assessed using the Robinson pipette method (Afnor, 2003). Total organic matter was quantified using the Walkley method (Walkley and Black, 1934). Soil pH was measured with a pH meter using a 1:2.5 (weight/volume) solution of soil mixed with demineralized water after 2 hours' agitation at room temperature (Fuentes et al., 2007). Calcium carbonate was determined using the Bernard method as described by Chamley (Chamley, 1966). Electrical conductivity in the soil extract was determined using a conductivity meter, with a 1:5 (weight/volume) solution of soil mixed with demineralized water after 2 hours stirring at room temperature (Fuentes et al., 2007). The method used to quantify total soil nitrogen is the Kjeldahl method. Assimilable phosphorus was analyzed using the Olsen method, which involves the use of sodium bicarbonate. Quantification of exchangeable potassium was carried out using normal ammonium acetate percolation extraction.

The method of McGrath and Cunliffe (McGrath and Cunliffe, 1985) and Garcia-Delgado (García-Delgado et al., 2007) was used for the determination of total heavy metals (macroelements and trace metals), in accordance with ISO 11466:1995 (F). One gram of soil, previously dried and ground, was mineralized in 10 ml of aqua regia (a mixture of 37% HCl and 65% HNO3 in a 3:1 ratio) at 150 °C for 2 hours using a heating block. The mineralization obtained was then adjusted to 50 ml with acidified distilled water (5% HNO_3 filtered through a 0.45 µm filter, and stored for subsequent analysis by plasma atomic emission spectrometry (ICP-AES) at the Cité de l'Innovation in Fez. Botanical identification was carried out using online databases and botanical references (Tela Botanica, 2012; Flore de l'Algérie et du Sahara (Quézel and Santa, 1962–1963); Flore vasculaire du Maroc (Fennane and Ibn Tattou, 2005).

RESULTS AND DISCUSSION

Textural analysis of the soils studied

Soil texture is an essential characteristic for maintaining soil equilibrium and exerting a considerable influence on plant growth (Gavrilescu, 2021). Because of its primary impact on water regime, aeration and porosity, soil texture contributes to the understanding of many soil functions. It also plays a crucial role in the interpretation of many of the parameters analyzed. Textural analysis using a Robinson pipette reveals significant differences between the two plots. In the first field (S1), the proportions of sand are significantly higher than in the second field (S2), reaching 65.5% near Ain el Houamed, whereas they do not exceed 33.5% in field S2 near Ain Hamra. As for the percentage of clay, it does not exceed 15.3% in site S1 and 37.8% in site S2, while the silt fraction shows slight variations, rising from 19.2% for site S1 to 28.6% for site S2 (see Table 1).

The textural triangle is an essential tool for visualizing and understanding the meaning associated with the name of a texture. It takes the form of a diagram illustrating the classification of textures according to percentages of sand, silt and clay. Using the textural triangle (Figure 1), we classified the soils studied into the following categories: S1 contains a significant proportion of silt and sand particles, and is of the sandy loam type (15.3% clay; 19.2% silt; 65.5% sand), a fine to medium texture ,This classification of S1 soils shows similarity to those observed in West Delhi, India (Rattan et al., 2005). S2 is a soil containing a significant proportion of silt and clay particles. It has a finer texture than sandy loam, which means it can retain water longer, and is of the clayey loam type (37.8% clay; 28.6% silts; 33.5% sand).

Chemical parameters

pH plays a considerable role in the development of spontaneous or cultivated plants, the results of our study reveal that pH values are relatively similar from one plot to another with a value of 7.72 for S1 and 8.04 for S2. Soils irrigated with spring water have higher pH values than the non-irrigated control soil, with values ranging from 7.46 to 7.94 (see Table 2). These results concurred the findings of (Singh and Verloo, 1996).The alkalinity of the pH limits the migration of heavy metals from the solid phase to the soil solution, and consequently to the plants (Thornton, 1996). In general, it should be noted that the pH values of the soils examined are basic in nature, which is beneficial for microbial activity and crop growth (Marschner, 1995).

The pH of both soils remains alkaline despite the addition of slightly acidic irrigation water, which could be attributed to the chemical composition of the soil's rocks and parent materials and its buffering capacity.

Analysis of organic matter

In the various samples reveals significant variations both between and within the different soils. Site S1 had an organic matter content of 1.17%, slightly higher than the 1.04% found in the control soil. Field S2, on the other hand, has a higher organic matter content of 3.41%, compared with 2.42% in the control soil. Both sites are rich in organic matter. Furthermore, the organic matter values documented for the investigated S1 exhibit similarities to those observed in The Kandialang-Djibock valley of Ziguinchor in Senegal (1.143%) (Dasylva et al., 2019).

Analyses of chemical parameters reveal a high concentration of total limestone in the soil sample taken near Ain el Haouamed (S1), reaching

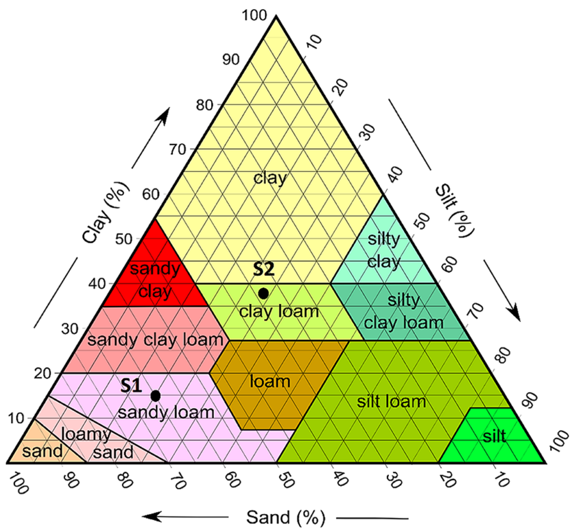

Figure 1. Triangular diagram of soil texture (soil textural triangle) (Science du sol | Parlons sciences)

Table 1. Textural analysis of studied soils

Soil	Latitude (N)	Longitude (W)	Sand (%)	Silt (%)	Clay (%)
S1	34°49'735	3°35'272	65.5	19.2	15.3
S2	34°73'611	3°94'254	33.5	28.6	37.8

39.6%. This high content enables this soil to be classified as calcareous (Baize, 2000). As for the soil sample taken where the waters of Ain Hamra discharge (S2), it shows an average percentage of total limestone, equivalent to 15.6%. It's important to note that limestone plays an important role in providing plants with the calcium they need. However, it can also hinder the absorption of certain elements essential to plants, such as iron and various trace elements (Rattan et al., 2005).

Active limestone levels in the soils of the two plots vary significantly, with a high level in plot S1 (8.5%) and a moderate level in plot S2 (6.5%). However, it is essential to emphasize that these levels of active limestone are significantly higher in the irrigated soils than in the control soil (Table 2). Electrical conductivity is an indicator of the concentration of soluble salts in the soil, enabling us to assess the soil's degree of salinity. Soil samples from the study sites show variable electrical conductivity values, classified according to the soil salinity classification criteria (Richard's Standards) (Guessir, 1995).

The results show that the soil in the first plot (S1) has a high conductivity of 12.12 mS/cm, falling within the range of 8 mS/cm to 16 mS/cm, which classifies it as a saline soil. This reflects the high natural mineralization of the Ain el Haouamed spring waters (Mouchane et al., 2024). In contrast, the soils of the second plot (S2) show low electrical conductivity values of 296 µS/cm, classifying them in the non-saline soil category, with conductivity values below 4 mS/cm. Soil analysis results indicate that electrical conductivity values are generally higher in soils irrigated with spring water (between 296 and 12,120 µS/cm) than in control soils not irrigated with spring water (between 168.5 and 3,700 µS/cm, see Table 2). This increase in salinity is attributable to the quality of the spring water containing soluble salts (calcium, magnesium, sodium, potassium), which are retained by the soil.

NPK bioavailable elements (Table 3 and Table 4)

According to the soil fertility standards established by Morocco's Directorate of Rural Equipment, the S1 soil is classified as low in total nitrogen, with a content of between 0.05% and 0.1%, i.e. 0.062%. Soil S2, on the other hand, is classified as very low in nitrogen, with a content of less than 0.05%, or 0.0035%. Nitrogen plays an essential role in amino acid synthesis and promotes plant tissue growth, making it a crucial factor (Ayers and Westcot, 1985). Nitrogen production in soil is inversely proportional to soil salinity.

Phosphorus is one of the major elements essential for plant growth and development, a cellular constituent and an energy carrier. As a cellular constituent, it participates, along with nitrogen, in plant growth, particularly root development (Soltner, 2003). Soils S1 and S2 are classified as very low in assimilable phosphorus, with percentages of less than 0.05%. This low phosphorus availability is particularly marked in calcareous soils. Potassium plays a crucial role in plant mineral nutrition, notably in regulating osmotic pressure and as an activator of enzymatic reactions linked to nitrogen

Table 2. Agronomic parameters of the soils studied

Soil	EC (µS/cm)	pH	Organic matter (%) OM	Total limestone (%) CaCO3	Actif limestone (%)
S1	12120	7,72	1.17	39.6	8.5
T1	3700	7,46	1.04	9.6	1.5
S2	296	8,04	3.41	15.6	6.5
T2	168,5	7,94	2.42	19.2	3

Table 3. Concentration of bioavailable elements in the soils studied

Specyfication		S1	S2
Total nitrogen	(%)	0.062	0.035
Assimilable phosphorus	(%)	0.0015	0.0061
	mg/kg	15	61
Exchangeable potassium	(%)	0.1651	0.072
	mg/kg	1651	720

metabolism (Séguret, 1998). However, in the soils studied, exchangeable potassium is in short supply, which is reflected in their classification. Soil S1 is classified as moderately rich in exchangeable potassium, while S2 is classified as poor.

Total macroelement concentrations

Total macroelement concentrations in the soils studied are shown in Table 5. The total calcium concentration is 50 mg/g DW in soil S1, compared with 11.51 mg/g DW in the control soil. It can be seen that the total calcium concentration in soil S1 is higher than that in the control soil. This observation can be attributed to the significant uptake of calcium by the soil from Ain el Haouamed water. In contrast, the calcium concentration in soil S2 is close to that of the control soil, with 17.60 mg/g DW in S2 compared with 24.82 mg/g DW in the control soil. This may be explained by the fact that the soil studied did not absorb a significant amount of calcium, perhaps due to its texture. Total magnesium concentration was 13.22 mg/g DW in soil S1, compared with 0.69 mg/g DW in the control soil, and 5.49 mg/g DW in soil S2, compared with 1.97 mg/g DW in the control soil. Total magnesium concentrations in both soils are higher than in the control soil. This observation can be attributed to the irrigation of this soil with water from the Ain el Haoumed spring, where the concentration of this element is very high. The total potassium level in soil S1 is 3.47 mg/g DW, compared with 0.63 mg/g DW in the control soil. The total potassium concentration in soil S1 is higher than in the control soil, reflecting the richness of Ain el Haoumed water in this element. In contrast, the potassium concentration in soil S2 is similar to that in the control soil, with 3.29 mg/g DW in S2 and 3.19 mg/g DW in the control soil. Studies on the concentration of macroelement in soil were addressed from different aspects, such as those carried out by Bourioug (Bourioug et al., 2015).

Trace metals elements (TME) (Table 6)

The total arsenic (As) concentration in soil S1 reached 0.014 mg/g DW, exceeding that recorded in soil S2 and the control soils. Total iron content varies between soils, with high values in S1 and S2, respectively 6.84 mg/g and 7.83 mg/g DW, reflecting the high concentrations of this metal in spring waters. With regard to metals such as cadmium (Cd), cobalt (Co) and lead (Pb), the soils studied, as well as the control soil, show very low total concentration values, below 0.01 mg/g DW. However, it should be noted that there is an enrichment in other metals in both soils compared to the control soil.

Total copper (Cu), nickel (Ni) and zinc (Zn) levels are higher in S2 than in S1. Total selenium (Se) concentrations are very high in all the soils studied, exceeding 50 mg/g DW. However, total chromium (Cr) concentrations remain relatively low, at around 0.007 mg/g DW for S1 and 0.017 mg/g DW for S2. It is important to note that total levels of trace metals (TME) vary considerably from one site to another, which is partly due to the textural differentiation of the soils and consequently strongly affects plant growth and development in each environment studied. There is a similarity in the value of iron with the values obtained by Belaid in Tunisia (Belaid et al., 2012), but there is a significant difference in the other elements. In addition, there are other studies that addressed soil irrigated with sludge and its effects on plant growth (Corbel et al., 2016).

Table 5. Total concentrations (mg/g DW) of macroelements in the soils studied

Specification	Ca	Mg	K	P
S1	50.00	13.22	3.47	0.48
T1	11.51	0.69	0.63	0.08
S2	17.60	5.49	3.29	0.58
T2	24.82	1.97	3.19	0.28

Table 4. Soil fertility standards (Directorate of Rural Equipment, Morocco)

Specification	Total nitrogen (%)	Total phosphorus (%)	Assimilable phosphorus (%)	Total potassium (%)	Assimilable potassium (%)
Very rich	+0.3	+3	+0.8	+8	+0.9
Rich	0.15 to 0.3	1.5 to 3	0.3 to 0.8	4 to 8	0.3 to 0.9
Moderately endowed	0.1 to 0.15	0.5 to 1.5	0.1 to 0.3	2 to 4	0.15 to 0.3
Poor	0.05 to 0.1	0.02 to 0.5	0.05 to 0.1	1 to 2	0.05 to 0.15
Very poor	-0.05	-0.02	-0.05	-1	-0.05

Table 6. Total concentrations (mg/g DW) of trace metals in the soils studied

Specification	As	Fe	Cd	Co	Cr	Cu	Ni	Pb	Se	Zn
S1	0.014	6.84	< 0.01	< 0.01	0.007	0.024	0.014	< 0.01	>50	0.089
T1	0.011	1.64	< 0.01	< 0.01	0.001	0.001	0.002	< 0.01	20.76	0.010
S2	0.005	7.83	< 0.01	< 0.01	0.017	0.034	0.020	< 0.01	>50	0.106
T2	0.006	11.44	< 0.01	< 0.01	0.013	0.020	0.013	< 0.01	49.47	0.058

Inventory of common plants near thermal springs

The plant diversity of a plot of land is affected by a number of factors, including the type of soil, the physico-chemical characteristics of the water, and the nutritional requirements of the plants growing in it. soil characteristics, such as texture, mineral composition, pH and nutrient availability, play a crucial role in the growth and diversity of plants on a given site. In addition, the particular nutritional requirements of plants can influence the plant composition of a site, as different plant species have diverse nutrient needs.

The site of the two springs studied has a considerable diversity of plant species, including *Tamarix gallica, Inula viscosa, Phragmites australis, Typha angustifolia, Matricaria chamomilla, Juncus acutus, Carex sylvatica*. These plants can show a certain tolerance to different conditions, particularly with regard to climate, the type of water and specific soils, as well as their composition. Alongside source S1, we identified three types of plant (see Table 7): *Matricaria chamomilla* L. is a cool-climate species growing in areas with temperatures between 7 and 26 °C. It is a medicinal plant native to southern and eastern Europe. It is also cultivated in Germany, Hungary, France, Russia, Yugoslavia and Brazil. Plants can be found in north Africa (Morocco, Algeria) (Ivens, 1979). Chamomile thrives in rich, light, well-drained siliceous soils, tolerates a pH of 4.5 to 7.5 and grows in full sun (Alia, 2020). In addition to its pharmaceutical uses, chamomile oil is widely used in perfumery, cosmetics and aromatherapy, as well as in the food industry (Lal et al., 1993; Misra et al., 1999).

Juncus acutus grows on all types of soil, from flooded areas to dry areas such as dunes, meadows and lowland forests (Fiche_ZH_BZH Juncus_acutus). It is a powerful, sharp species with an Atlantic sub-Mediterranean distribution, and is abundant on the Mediterranean coast (Algeria, Egypt and Morocco) (Provost and Bournérias, 1993). Juncus seeds are used in the Orient as a remedy for diarrhea, and the fruits in decoction are indicated for diabetes (Tackholm and Drar, 1950; Benkhnigue et al., 2014).

Carex sylvatica covers a vast altitudinal range, existing in France at altitudes of between 0 and 1,700 meters. Wood sedge is most often found in forest cover, where it finds the shade, moisture and nutrients it needs for its biology. It is a neutrocline, sciaphilous, mesophilous species that thrives on cool, deep soil rich in clay and silt. It is found in Europe, temperate Asia, north America (Rameau et al., 1993). and north Africa (Morocco, Algeria, etc.) (Maire, 1952). This plant thrives in the cool undergrowth of boreal regions, but can also be used in the garden. It makes an ideal ground cover at the foot of shrubs. The Lapps also used it as insulating wadding for their homes (Laîche des bois).

Near the "Ain Hamra" or "Ain Ar-Rahma" spring, characterized by thermal waters rich in iron, carbon dioxide (CO_2) and sulfates (Taybi et al., 2019; Mouchane et al., 2024), The S2 site is irrigated by these waters and features a wide diversity of plant species, of great interest for any scientific study, whether biological or ecological, notably *Tamarix gallica, Inula viscosa, Phragmites australis, Typha angustifolia* (see Table 8).

Tamarix gallica is distributed along the Mediterranean coast, in Provence, Languedoc and Roussillon; it grows upstream in Vaucluse, Drôme and Ardèche; Corsica. Spain and Portugal, Balearic Islands, Sardinia, Sicily, Italy, Dalmatia; Algeria, Morocco, Canary Islands (Crins, 1989). It is mainly found in salty regions, between the inter-dunal zones of the desert (KalamUrfi et al., 2016). This plant is widely used in traditional medicine as a prophylactic and therapeutic remedy against malaria (Tagarelli et al., 2010). It is also used to treat leucoderma (KalamUrfi et al., 2016).

Inula viscosa (the slimy inula) is a Mediterranean "weed" that grows along roadsides, on fallow land or in the middle of open scrubland on

Table 7. Plant species found near the Ain El Haouamed thermal spring

Scientific name: *Matricaria chamomilla* Common name: Wild Chamomile  Photo taken on March 20, 2023	Classification (Djoubani et al., 2017) Reign — Plantae Sub-reign — Viridaeplantae Division — Magnoliophyta Class — Magnoliopsida Subclass — Magnoliidae Order — Asterales Family — Asteraceae Gender — *Matricaria L* Species — *Chamomilla*	Botanical description This is an aromatic, herbaceous and slightly fruity annual plant (Zadeh et al., 2014; Piri et al., 2019), measuring between 15 and 80 cm in height. Stems are erect and sometimes branched. Leaves are very finely cut and hairless (Lim, 2012). Flowers are yellow in the center and white outside, grouped in solitary flower heads. The seed-containing fruits are achenes, yellowish when ripe (Doctissimo, 2017).
Scientific name: *Juncus acutus* Common name*:* Spiny rush  Photo taken on March 20, 2023	Classification (Hagemeyer, 1996) Reign — Plantae Sub-reign — Viridaeplantae Division — Magnoliophyta Class — Equisetopsida Subclass — Magnoliidae Order — Juncales Family — Juncaceae Genus — *Juncus* Species — *acutus*	Botanical description Spiny rush *(Juncus acutus)* is a glabrous perennial growing to around 1-meter-tall, with a thick, fibrous stump. It has sturdy, tufted stems, radical, sparse leaves and russet-green panicle-shaped flowers (tela botanica).
Scientific name: *Carex sylvatica* Common name: Wood sedge  Photo taken on March 20, 2023	Classification (Kartesz and Kartesz, 1994) Reign — Plantae Sub-reign — Viridaeplantae Division — Magnoliophyta Class — Equisetopsida Subclass — Magnoliidae Order — Cyperales Family — Cyperaceae Gender — *Carex* Species — *sylvatica*	Botanical description 30–80 cm tall, glabrous perennial with a short, grassy stump. Stem bent at the top, trigonal, smooth. Leaves soft, 3 to 6 mm wide, scabrous; male spike solitary, linear, pale russet; 3 to 6 female spikes spaced apart, spindly, linear-oblong, loose, leaning on long peduncles. The fruit is an achene. Flowering generally takes place from April to July. (Thomas, 2017).

Table 8. Plant species found near the "Ain Hamra" thermal spring

Scientific name: *Tamarix gallica* Common name: *Athel tamarisk*  Photo taken on August 10, 2023	Classification (FELLAH, 2019) Reign Plantae Sub-reign Tracheobionta Division Magnoliophyta Class Magnoliopsida Subclass Dilleniidae Order Violales Family Tamaricaceae Gender *Tamarix* Species *gallica*	Botanical description Tamarix gallica is a shrub that can reach 8 m in height. Its bark is blackish brown or dark purple. Tamarix gallica flowers from early June to August on the previous year's shoots (Baltet, 1887). The flowers are hermaphroditic and polonized by bees (Baum, 1978). Leaves are triangular, longer than they are wide, embracing the branch at 180° (Allred, 2002).
Scientific name: Inulaviscosa Common name*: Viscose inula*  Photo taken on August 10, 2023	Classification (Quezel and Santa, 1963) Reign Plantae Sub-reign Viridaeplantae Division Coniferophyta Class Magnoliopsida Subclass Magnoliidae Order Asterales Family Astéracées Gender *Inula* Species *viscosa*	Botanical description Viscose Inula (Dittrichia viscosa) is a large herbaceous plant, its branched, woody stems forming a small bush with dense foliage. The sessile leaves are wavy, toothed, acute, rough and covered on both sides with viscous glands (Quezel and Santa, 1963). Its lignified taproot can be up to 30 cm long (Haoui et al., 2015). The peripheral flowers are liguliform, those in the center are tubular and the fruits are achenes (Bensegueni Tounsi, 2001).
Scientific name: *Phragmites australis* Common name: The common reed  Photo taken on August 10, 2023	Classification (Quezel and Santa, 1963) Reign Plantae Sub-reign Viridaeplantae Division Magnoliophyta Class Equisetopsidae Subclass Magnoliidae Order Cyperales Family Poaceae Gender *Phragmites* Species *Australis*	Botanical description Common reed (Phragmites australis) is a thick, non-woody, vascular perennial that is thinner than a finger and fragile. This plant bears hemicryptophytic/geophytic rhizomes and stems that measure up to 6 meters in height and 4 to 10 millimeters in diameter (Bonanno and Giudice, 2010). The leaves are large, 1-3 cm wide, rough at the edges, with a ligule formed by a row of short hairs (Tela Tela Botanica, 2023). The fruit is in the form of achenes called caryopses, golden to brown in color, with white silky hairs where the capsule contains a single black seed.
Scientific name: *Typha angustifolia* Common name: narrowleaf cattail (Bourdi, Berdi)  Photo taken on August 10, 2023	Classification (Djebrouni et al., 2020) Reign Plantae Sub-reign Viridaeplantae Division Magnoliophyta Class Equisetopsidae Subclass Magnoliidae Order Typhales Family Typhaceae Gender *Typha* Species *Angustifolia*	Botanical description *Typha angustifolia* is an erect, rhizomatous perennial with flowers borne on a slender stem 1 to 3 m high. Leaves are long, linear, strongly plano-convex, 3-8 mm wide, sometimes wider, dark green, sheathed at the base, sheaths usually auriculate; leaves extend well beyond flowering spikes, sometimes up to half the length of the spike. The roots are fibrous and the flowers are unisexual. The pistillate spike is borne below the staminate spike and is generally separated from it by a space of 5 to 120 mm. (Grace and Harrison, 1986)

salty soils, wet meadows and riverbanks (Quezel and Santa, 1963). The genus Dittrichia is widely distributed throughout the Mediterranean basin, in Europe, Asia and Africa (Egypt, Algeria, Morocco) (Benhammou, 2006; Benguerba, 2008). slimy inula also occurs in surfaces where soils have high concentrations of magnesium and nitrogen (Parolin et al., 2014). It is used for its anti-inflammatory, antidiabetic, antipyretic, antiseptic, antiulcerogenic and antifungal activities against dermatophytes, as well as for treating gastroduodenal disorders (Deghdak and Zaiter, 2014).

Phragmites australis this hydrophilic species occurs naturally in wetlands or floodplains, such as freshwater or brackish marshes (Meyerson et al., 2000). It is found on every continent (except Antarctica) and in almost every biome, with the exception of arctic tundra and equatorial rainforests (Haslam, 1972).Common reed is a cosmopolitan species, meaning it is found in every region of the world. Colonies are found in Africa, America, Asia, Australia, Europe and New Zealand. In Morocco, it is found in the Saharan Atlas, central Morocco (northern part), central Morocco (southern part), the High Atlas, southern steppe Morocco, the Middle Atlas, the Rif and the Souss Plain (Jahandiez and Maire, 1931). Reed usually grows on soils with a pH of 5.5 to 8.1 (Haslam, 1972). It tolerates well moderate salinity levels below 25‰ (Meyerson et al., 2000). Also, it can grow on both mineral (especially clayey) and organic soil (with an organic content of 1 to 97%). Phragmites australis is used as a treatment for bronchitis, diarrhea, fever and stomach pains, and seed powder is used as an ingredient in burn creams (Brink and Achigan-Dako, 2012).

Typha angustifolia is a malarial plant with a wide geographic distribution in the Northern Hemisphere: Europe, Asia, north America and certain wetlands in Peru and Chile. The species is also widespread in the Mediterranean region and North Africa, where populations appear to be stable in Morocco and Algeria. It grows in ponds and rivers (Grace and Harrison, 1986). This plant is widespread, semi-aquatic, hardy and large-growing, both decorative and useful for its filtering properties, but should be reserved for large basins and ponds due to its vigor (Gèze, 1922). It has been used in traditional Chinese medicine with the ability to improve microcirculation, inhibit the immune system (Qin and Sun, 2005), induce uterine contractions, treat atherosclerosis and wound healing (Chen et al., 2012).

CONCLUSIONS

The aim of the current research was to determine the quality of the soil and the plants growing in the vicinity of two thermal springs. Soil analyses led to the following conclusions. The soil near Ain el Houamed, a spring very rich in CO_2, iron and minerals, is a sandy loam with a slightly basic pH, a high limestone content and high electrical conductivity due to the quality of the spring water containing soluble salts. Phosphorus, potassium and nitrogen levels are relatively low. The soil is rich in calcium (50 mg/g DW) and magnesium (13.22 mg/g DW). In terms of metal concentrations, the soil is characterized by high selenium and iron values. The characteristic flora of this soil consists of Matricaria chamomilla, Juncus acutus and *Carex sylvatica*.

While for Ain Hamra, which is a carbonated, ferruginous thermal spring well-known for its richness in minerals, surrounded by the presence of various types of plants including *Tamarix gallica*, *Inula viscosa*, *Phragmites australis*, *Typha angustifolia*. These plants grow in a silty-clay soil with a basic pH with slightly different concentrations compared to the soil of Ain el Houamed for most parameters.

Acknowledgments

Mohamed Mouchane wish to thank the technical staff of the laboratory Ferticonseil (National School of Agriculture of Meknes), For the immense understanding, assistance, and support given in the realization of this fruitful work.

REFERENCES

1. AFNOR N. 2003. X31-107; Qualité du Sol—Détermination de la Distribution Granulométrique Des Particules du Sol-Méthode à la Pipette. AFNRO: Saint-Denis, France.
2. Akhter S, Bhat MA, Hashem A, et al. 2023. Profiling of Antibiotic Residues in Soil and Vegetables Irrigated Using Pharmaceutical-Contaminated Water in the Delhi Stretch of the Yamuna River, India. Water. 15(23), 4197.
3. Alia BB. 2020. Différentes méthodes d'extraction de l'espèce Matricariachamomilla:(analyse chimique et étude biologique).
4. Al-Kayssi AA. 2023. Role of alternate and fixed partial root-zone drying on water use efficiency and growth of maize (*Zea mays* L.) in gypsiferous

soils. International Soil and Water Conservation Research. 11(1), 145–158.

5. Allred KW. 2002. Identification and taxonomy of Tamarix (*Tamaricaceae*) in New Mexico. Desert Plants.in Tabetn A, Boukhari A (2019)., Estimation of Total Phenolic Content of the Algerian Plant Tamarix gallica, World J Environ Biosci, 2019, 8(1), 25- 29.
6. Ayers RS, Westcot DW. 1985. Water quality for agriculture. Food and Agriculture Organization of the United Nations Rome.
7. Baize D. 2000. Guide des analyses en pédologie. 2éd. INRA, Paris. 257.
8. Baltet C. 1887. Les arbustes de pleine terre, paris g. masson, éditeur libraire de l'acadêmie de médecine i20, boulevard s'-germnin, en face de l'école de médecine.
9. Baum BR. 1978. The genus Tamarix Israel Academy of Sciences and Humanities. Jerusalem. xii. 209.
10. Belaid N, Neel C, Lenain JF, et al. 2012. Assessment of metal accumulation in calcareous soil and forage crops subjected to long-term irrigation using treated wastewater: Case of El Hajeb-Sfax, Tunisia. Agriculture, Ecosystems & Environment. 158, 83–93.
11. Benguerba A. 2008. Etude phytochimique et de la phase butanolique de l'espèce Inula crithmoides L., Thèse de magister. Université Mentouri Constantine. 101 p.iscosa dela région de Tlemcen. Thèse de Magister. Université Aboubekr Belkaid. 145.
12. Benhammou N. 2006. Etude des activités antimicrobiennes et anti oxydantes des huiles essentielles et des composes phénoliques de Pistacia lentiscus, Pistacia atlantica, et Inula viscosa dela région de Tlemcen [PhD Thesis]. Thèse de Magister. Université Aboubekr Belkaid. 145.
13. Benkhnigue O, Akka FB, Salhi S, et al. 2014. Catalogue des plantes médicinales utilisées dans le traitement du diabète dans la région d'Al Haouz-Rhamna (Maroc). J Anim Plant Sci. 23(1), 3539–68.
14. Bensegueni Tounsi L. 2001. Etude in vitro de l'effet antibactérien et antifongique de: Inula viscosa-Lawsonia inermis- Asphodelus microcarpus- Aloe vera-Juniperus oxycedrus. Mémoire de Master en Médecine Vétérinaire. Université de Constantine. 110.
15. Bonanno G, Giudice RL. 2010. Heavy metal bioaccumulation by the organs of Phragmites australis (common reed) and their potential use as contamination indicators. Ecological Indicators. 10(3), 639–645.
16. Boujraf A, Dallahi Y, Dahmani J, et al. 2023. Effect of plant communities and ecological parameters on soil organic carbon stocks in the Mamora Forest, Morocco. Journal of Ecological Engineering. 24(5).
17. Bourioug M, Gimbert F, Alaoui-Sehmer L, et al. 2015. Effects of sewage sludge amendment on snail growth and trace metal transfer in the soil-plant-snail food chain. Environ Sci Pollut Res. 22(22), 17925–17936.
18. Brink M, Achigan-Dako EG. 2012. Plant Resources of Tropical Africa 16 Fibres. EconomicBotany. 66(3), 312-313.
19. Chamley H. 1966. Guide des techniques du laboratoire de géologie marine. Faculté des Sciences.
20. Chen P, Liu S, Dai G, et al. 2012. Determination of typhaneoside in rat plasma by liquid chromatography–tandem mass spectrometry. Journal of Pharmaceutical and Biomedical Analysis. 70, 636–639.
21. Corbel S, Bourioug M, Alaoui-Sossé L, et al. 2016. Effects of repeated soil irrigation with liquid biological paper sludge on poplar Populus alba saplings: potential risks and benefits. Environ Sci Pollut Res. 23(21), 21584–21593.
22. Crins WJ. 1989. The Tamaricaceae in the southeastern United States. Journal of the Arnold Arboretum. 70(3), 403–425.
23. Dasylva M, Ndour N, Diédhiou MAA, et al. 2019. Caractérisation physico-chimique des sols des vallées agricoles de la commune de Ziguinchor au Sénégal. European Scientific Journal.
24. Deghdak H, Zaiter R. 2014. Mémoire en Master Thème : Evaluation De L'activité Antioxydante Et Anti Inflammatoire De La Plante Médicinal Algérienne Inula Viscosa .Université constantine1.
25. Djebrouni C, Bouafia W, Benfridja LE. 2020. La phytoremédiation des eaux de surface par les macrophytes aquatiques: cas des métaux lourds [PhD Thesis]. Université de Jijel. Available from http://dspace.univ-jijel.dz:8080/xmlui/handle/123456789/8455.
26. Djoubani K, Hamadouche N, Boudraa O. 2017. Evaluation du pouvoir antimicrobien de plusieurs extraits polyphénolique de deux espèces végétales Chamaeme lumnobil L. et Matricaria chamomilla L. Mémoire master. Université M'hamed Bougara Boumerdès.
27. Doctissimo. 2017 Médecine Douce. Phytothérapie. Plantes Médicinales. https://www.doctissimo.fr/html/sante/phytotherapie/plante-medicinale/matricairecamomille-allemande.htm.
28. FELLAH O. 2019. Effet des facteurs environnementaux sur la variation de quelques métabolites secondaires dans deux espèces médicinales : Tamarix gallica L. (Tamaricaceae) et Rosmarinus officinalis L. (Lamiaceae). Thèse de doctorat, Université Badji Mokhtar Annaba.
29. Fiche_ZH_BZH_Juncus_acutus.https://www.cbnbrest.fr/files/Fiche_ZH_BZH_Juncus_acutus_20230112.pdf. (Consulte le 09/09/2023)
30. Fuentes D, Valdecantos A, Cortina J, et al. 2007. Seedling performance in sewage sludge-amended degraded mediterranean woodlands. ecological engineering. 31(4), 281–291.
31. García-Delgado M, Rodríguez-Cruz MS, Lorenzo

LF, et al. 2007. Seasonal and time variability of heavy metal content and of its chemical forms in sewage sludges from different wastewater treatment plants. Science of the Total environment. 382(1), 82–92.

32. Gavrilescu M. 2021. Water, soil, and plants interactions in a threatened environment. Water. 13(19), 2746.
33. Gèze J-B. 1922. Utilisation des Typha en France. Journal d'agriculture traditionnelle et de botanique appliquée. 2(14), 551–557.
34. Grace JB, Harrison JS. 1986. THE Biology of Canadian Weeds, 73. *Typha latifolia* L., *Typha angustifolia* L. and *Typha xglauca* Godr. Can. J. Plant Sci. 66(2), 361–379. https://doi.org/10.4141/cjps86-051.
35. Guessir H. 1995. Étude de l'impact de l'irrigation par les eaux usées brutes sur la qualité physico-chimique du sol et de la nappe phréatique dans la région de Sidi Bennour (Maroc).
36. Hagemeyer J. 1996. Salt in plant Ecophysiology classification of plants halophytes. New York: John Wiley and Sons. 176–181.
37. Haoui IE, Derriche R, Madani L, et al. 2015. Analysis of the chemical composition of essential oil from Algerian Inula viscosa (L.) Aiton. Arabian Journal of chemistry. 8(4), 587–590.
38. Haslam SM. 1972. Phragmites communis Trin. (*Arundo phragmites* L.,? *Phragmites australis* (Cav.) Trin. ex Steudel). The journal of ecology.:585–610.
39. Ivens GW. 1979. Weeds OF note-stinking mayweed. New Zealand Journal of Agriculture, 138(3), 21.
40. Jahandiez E, Maire R. 1931. Catalogue Des Plantes Du Maroc:(Spermatophytes et Ptéridophytes). Tome Premier. Ptéridophytes, Gymnospermes et Monocotylédones. Minerva.
41. KalamUrfi M, Mujahid M, Badruddeen, et al. 2016. Tamarix gallica: For traditional uses, phytochemical and pharmacological potentials. 8, 809–814.
42. Kartesz JT, Kartesz R. 1994. A synonymized checklist of the vascular flora of the United States, Canada, and Greenland. 2nd edition. 2 vols. Timber Press, Portland.
43. Laîche des bois (Carex sylvatica). https://www.picturethisai.com/fr/wiki/Carex_sylvatica.html(Consulté le 09/09/2023).
44. Lal RK, Sharma JR, Mishra HO, et al. 1993. Induced floral mutants and their productivity in German chamomile (MATRICARIA-RECUTITA). Indian Journal Of Agricultural Sciences. 63(1), 27–33.
45. Lim TK. 2012. Matricaria chamomilla. Edible Medicinal And Non-Medicinal Plants. p. 397–431.
46. Maire R. 1952. Flore de l'Afrique du Nord (Maroc, Algérie, Tunisie, Tripolitaine, Cyrénaïque et Sahara).
47. Marschner H. 1995. Mineral nutrition of higher plants.. ed. 2.
48. Martínez Barroso P, Vaverková MD. 2020. Fire effects on soils-A pilot scale study on the soils affected by wildfires in the Czech Republic. Journal of Ecological Engineering. 21(6), 248–256.
49. McGrath SP, Cunliffe CH. 1985. A simplified method for the extraction of the metals Fe, Zn, Cu, Ni, Cd, Pb, Cr, Co and Mn from soils and sewage sludges. J Sci Food Agric. 36(9), 794–798.
50. Meyerson LA, Saltonstall K, Windham L, et al. 2000. A comparison of Phragmites australis in freshwater and brackish marsh environments in North America. Wetlands Ecology and Management. 8(2/3), 89–103.
51. Misra N, Luthra R, Singh KL, et al. 1999. Recent advances in biosynthesis of alkaloids.
52. Mouchane M, Taybi H, Bargach K, et al. 2024. Comparative study of two ferruginous thermal sources, carbogaseous in the Eastern Rif, Morocco. Chemistry Africa.
53. Mourelle ML, Gómez CP, Legido JL. 2023. Hydrobiome of thermal waters: potential use in dermocosmetics. Cosmetics. 10(4), 94.
54. Parolin P, Scotta MI, Bresch C. 2014. Biology of Dittrichia viscosa, a Mediterranean ruderal plant: a review. Phyton Int. J. Exp. Bot. 83, 251–262.
55. Piri E, Mahmoodi Sourestani M, Khaleghi E, et al. 2019. Chemo-diversity and antiradical potential of twelve matricaria chamomilla L. Populations from Iran: Proof of ecological effects. Molecules. 24(7), 1315.
56. Provost M, Bournérias M. 1993. Atlas de répartition des plantes vasculaires de Basse-Normandie. Université de Caen.
57. Qin F, Sun H-X. 2005. Immunosuppressive activity of Pollen Typhae ethanol extract on the immune responses in mice. Journal of ethnopharmacology. 102(3), 424–429.
58. Quezel P, Santa S. 1963. Nouvelle flore de l'Algérie et des régions désertiques méridionales.
59. Rameau J-C, Mansion D, Dumé G. 1993. Flore forestière française(guide écologique illustré. Tome 2, Montagnes).
60. Rattan RK, Datta SP, Chhonkar PK, et al. 2005. Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater—a case study. Agriculture, ecosystems & environment. 109(3–4), 310–322.
61. Science du sol | Parlons sciences. https://parlonssciences.ca/ressources-pedagogiques/documents-dinformation/science-du-sol. (Consulté le 13 février 2024).
62. Séguret F. 1998. Etude de l'hydrodynamique des procédés de traitement des eaux usées à biomasse fixée-application aux lits bactériens et aux biofiltres [PhD Thesis]. Université Sciences et Technologies-Bordeaux I.
63. Shin S, Aziz D, El-sayed ME, et al. 2022. Systems thinking for planning sustainable desert agriculture systems with saline groundwater irrigation: A

review. Water. 14(20), 3343.
64. Singh SP, Verloo MG. 1996. Accumulation and bioavailability of metals in semi-arid soils irrigated with sewage effluents.
65. Soltner D. 2003. Les bases de la production végétale.
66. Tackholm V, Drar M. 1950. Flora of Egypt, vol. 11. Fouad I University Press, Cairo.
67. Tagarelli G, Tagarelli A, Piro A. 2010. Folk medicine used to heal malaria in Calabria (southern Italy). J Ethnobiology Ethnomedicine. 6(1), 27.
68. Taybi H, Bargach K, Boulfia M, et al. 2019. Etude géologique et qualités physico-chimique et bactériologique des eaux thermales de la source "Ain Hamra" de la Province de Taza (Rif Oriental -Maroc). Journal of Water and Environment Technology. 1, 443–451.
69. Tela Tela Botanica. 2023. Base de Données Nomenclaturale de la Flore de France par Benoît Bock, BDNFF v4.02. (telabotanica.org).
70. Tela Botanica. https://www.tela-botanica.org/bdtfx-nn-75471 (Consulté le 09/09/2023).
71. Thomas C. 2017. la Laîche des bois, Carex sylvatica subsp. sylvatica Huds., 1762. du ravin obscur des Auripes (Gordes), une nouvelle espèce pour le département du Vauclus.
72. Thornton I. 1996. Risk assessment related to metals: the role of the geochemist. In: Report of the International Workshop on Risk Assessment of Metals and their Inorganic Compounds, Angers, France.
73. Walkley A, Black IA. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil science. 37(1), 29–38.
74. Zadeh JB, Kor NM, Kor ZM. 2014. Chamomile (Matricaria recutita) as a valuable medicinal plant. International journal of Advanced Biological and Biomedical Research. 2(3), 823–829.